NERRS Science Collaborative Progress Report for Period 09/01/10 through 02/28/11

Project Title: Nitrogen Sources and Transport Pathways: Science and Management Collaboration to Reduce Nitrogen Loads in the Great Bay Estuarine Ecosystem

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*Figures displayed at end of document.
Figure 1: Land use and extensive sampling sites in the Great Bay watershed.
Figure 2: Preliminary nitrate concentration data at extensive stream sites.
Figure 3: Preliminary total dissolved nitrogen (TDN) concentration data at extensive stream sites.

A. Progress overview: Overall goal of project and brief summary of what we planned to accomplish during this period including progress on tasks for this reporting period.

The Great Bay (GB) National Estuarine Research Reserve (NERR) ecosystem has experienced a decline in ecosystem health over the last 25 years and increased nitrogen (N) concentrations in GB have contributed to habitat degradation. The impacts from excess N have been identified as a driver of reduced eelgrass coverage, decreased oyster populations, and periodic depletion of dissolved oxygen in the Bay. As a result, the GB has been listed as "impaired" (i.e., Federal Clean Water Act) by elevated N resulting from both point and non-point sources (NPS) in the watershed. The project aims to address the gaps in our basic understanding of NPS N sources and transport in GB tributaries, with specific objectives to: 1) map the nitrogen hot spots in surface waters within the watershed; 2) identify the sources of nitrogen that result in these hot spots; 3) characterize the flow paths that deliver N to these hot spots; 4) determine whether N removal occurs in vegetated riparian buffers with different land uses; 5) quantify nitrate attenuation in tributary streams and the main stem; and 6) integrate the results of these scientific investigations and make them accessible and useful to environmental managers and stakeholders.

An integral part of this project has been to address the scientific issues through successful collaboration with the stakeholder and residential community. During this 6 month reporting period, our plans were to work on objectives 1, 5 and 6 and accomplish the following tasks: 1) select approximately 250 extensive stream sites using ArcGIS and available information on catchment human population density, impervious surfaces and land use; 2) sample these extensive stream sites; 3) begin determining N uptake in river reaches with mass balance; and 4) conduct stakeholder meetings and integrate feedback. Tasks 1 and 2 were completed and samples have been analyzed for N concentrations to begin assessing "hot spots" (a task that was scheduled for the next reporting period). Task 3 has been initiated, but the majority of the GIS analysis for this will occur over the next 6 months. See section B for progress on task 4.

B. Working with Intended Users

Progress on tasks related to the integration of intended users into the project for this reporting period.

1. Synthesized needs and concerns expressed from Southeast Watershed Alliance (SWA), GBNERR, local watershed associations, and the Piscataqua Region Estuaries Project (PREP) to frame the questions that drove the research.

2. Attended a SWA meeting (12/01/10). SWA is an alliance of municipalities in New Hampshire that is working to develop a regional collaborative framework for improving and protecting water quality and meeting clean water act standards. We were scheduled to present our project and get some feedback at the December meeting, but our presentation was taken off the agenda due to concerns about addressing a contentious topic early on in the genesis of SWA. Nonetheless, project team members networked with key watershed stakeholders to discuss ways of reaching out to communities and organizations concerned about the GB watershed. Interest in our project team helping to sponsor a nitrogen symposium was conveyed. Out of this grew the idea of holding a nitrogen forum in March in collaboration with the Southeast Watershed Alliance and the Great Bay National Estuaries Research Reserve. At the N forum, project team will engage municipal SWA representatives, as well as policy-makers, in a discussion about NPS nitrogen and how the science of this project, can best inform decision-making.

3. Presented project overview and role of integration at the 4th Annual Lamprey River Science Symposium in January, 2011 and held a focus group to garner input on the research questions and other potential questions or concerns stakeholders would like to see incorporated into the project (see input from symposium in following sections).

4. The project team is currently developing a video presentation that will serve as a communication piece for local boards and commissions, as well as the public-at-large, to inform them about the state of Great Bay, the issues related to nitrogen, why it is of concern to communities watershed wide, and what the project is designed to generate in terms of useful information to land/watershed managers. Most importantly, the video

solicits feedback on the research questions and invites stakeholders to bring forth new questions that might be incorporated into the project by several outreach methods (i.e., emailing, website, or phone call) project team.

5. A UNH press release about the NERRS Science Collaborative project that outlined the project and invited stakeholders to contact the research team with questions and comments. Based on this press release, articles were published in the following seacoast-area and regional media outlets: *The New Hampshire* (UNH campus newspaper), Portsmouth Herald/Seacoast, Associated Press, and the Boston Herald. A radio interview with the PI was also conducted and aired by NH Public Radio.

6. The research team drafted an article for the public about the nitrogen problem facing Great Bay, what it means for the watershed, and how the project will help us better understand nitrogen sources, hot spots, and flow pathways, which will be critical to good decision-making. The article is being released in the Lee Town Newsletter.

7. An article on this project was published in the Great Bay Matters Winter 2011 Issue. Great bay Matters is the newsletter for the Great Bay Stewards and is sent to 1400 readers. This article was based on the NSC factsheet published by the NSC.

8. An article is being drafted for *Town & City*, a publication of the NH Local Government Center that goes to key officials in all 234 of the state's municipalities.

What we have learned as well as unanticipated challenges or opportunities.

One thing that we learned was that there are a number of people and organizations who would like to be engaged in a continuing discussion about the project. At least ten individuals expressed an interest in participating in more discussion. And over a dozen people signed up for an e-mail list that will provide updates about this project in the coming months.

In terms of challenges/opportunities, some participants at the Lamprey River Science Symposium stated that our research team needs to make information about nitrogen issues, and the project in general, more accessible to both community decision-makers as well as the public-at-large. Because the symposium was primarily aimed at the scientific community, this is an understandable response. It highlights the difficulties, however in issuing invitations to the public-at-large in order to make the scientific process as transparent as possible. The communication among scientists is absolutely essential, and cannot be replaced by a public-oriented symposium. Equally essential, however, is conveying this information to the public. Our current approach to dealing with this dilemma is to have additional meetings, with some targeted specifically toward the public.

Given that the science may not be digestible to decision-makers in its current form, we need to develop educational outreach that outlines the big picture (i.e. the research questions and implications for communities and the watershed as a whole), rather than delving deeply into the hard science and techniques, in public meetings specifically targeting a lay audience.

Partners involved.

1. Piscataquis River Estuaries Partnership (PREP)
2. University scientists focusing on the Great Bay watershed
3. Southeast Watershed Alliance
4. Great Bay National Estuaries Research Reserve
5. UNH Cooperative Extension
6. NH Water Resources Research Center
7. NH Department of Environmental Services/ Piscataqua Region Estuaries Partnership (via Phil Trowbridge)
8. Lamprey River Watershed Association (Dawn Genes)
9. Training for the Integration of Decision-Making and Ecosystem Science (TIDES) Program

Interactions with intended users have brought about some changes to our methods, including integration of intended users and project objectives.

Feedback from intended users was used to enhance the products that we will deliver from this project. For example, based on our extensive survey combined with the vetting with experts and community groups, we have adapted Objective 1 to include the development of the Great Bay landscape model. In the original proposal, we proposed to sample ~ 250 extensive sites one time throughout the 3-year study. However, during recent workshops with scientists and stakeholders regarding the challenges of how to measure "hot spots" on a larger spatial scale and their relationships to land use, we decided to sample these extensive sites several more times. This will give us information on any seasonal variation in stream chemistry so that we can build a model that predicts N concentrations based on landscape characteristics (e.g. land use, human population density, and impervious surface).

Interaction with intended users has prompted consideration of an additional analysis to our current method. Based on discussions and consultation with UNH hydrological scientists at recent workshops, we will consider conducting field experiments at intensive sites to profile nutrient and water chemistry variables across a storm event. This information can yield higher temporal resolution (e.g. 15 min intervals) of nutrient data to help pin-point N sources among land use factors, which otherwise may not be captured during monthly sampling.

In addition, much of the integration for phase 1 (research design) has taken place as the project was being conceptualized for the initial proposal. This was with our Intended User group 1, Regulatory framework and policy makers.

Input shared as a result of stakeholder engagement activities includes:

- Research outcomes that could specify down to specific land uses along the watershed and their particular role in contributing N to Great Bay and the watershed.....e.g. what can we say about the effect of buffers in communities that have them as opposed communities that don't (in streams/rivers where Federal law does not require them).

- At what geographic scale will we be able to draw correlations or causal relationships to land use characteristics and N hot spots and sources?
- The individuals who work with wastewater/septic municipalities want to learn more about how slope and soil type impact the flow of N spatially so that they can better implement their systems.
- How the science outcome information can help to support remediation strategies for NPS N.
- Another commented that knowing N sources will help us refine the tool box of potential remedies, since understanding N at the source is a useful strategy.
- There are many more stakeholders who need to be engaged.
- Several participants expressed an interest in being kept abreast of the project as it unfolds.
- Concern was expressed by a past coordinator of Great Bay stewards: We need to do a better job of translating the science to non-scientists.

How we anticipate working with intended users in the next six months.

We will continue to reach out to our Intended User groups 2 and 3, Municipal Watershed Management Network (of which the SWA is a key partner) and Watershed Associations on their terms and at their facility or wherever they prefer. We are in the process of developing a 'road show' that outlines the issue, why people should care, what the project goals are, and garners input on what questions/concerns should be incorporated into the project when feasible. The video mentioned above will also be developed and shared with Planning Boards, watershed associations, Conservation Commissions, public access cable channels, etc. The preliminary results of our extensive sampling campaign will be also be shared with the public via a project website and with the help of New Hampshire Public Television, which has offered to help in the dissemination of information through a Great Bay "micro-website" that they are developing and via radio broadcasts.

Finally, in the next 6 months phase II will begin whereby the preliminary results and analyses will be shared with the public via a project website and with the help of New Hampshire Public Television, which has offered to help in the dissemination of information via a Great Bay website they are developing and via radio broadcasts.

Also, our collaboration work with the SWA is beginning to take shape and get into a more productive realm. The SWA has been grabbling with internal organizational issues and this has prevented our being able to engage them to the degree we had hoped. But as has been noted prior in this report we have been asked to help the SWA develop and organize a Science Symposium on Great Bay. The goals of the symposium are: To develop a strong science-based foundation to support management decisions and solutions in the Coastal Watershed by:

1. Identifying and summarize existing technical information relevant to water quality impairments in the coastal watershed.
2. Determine whether the existing (and currently being acquired) information is adequate to support regulatory, management and remediation decision.

3. Identify gaps in the current knowledge; develop a priority task list for additional information.

These goals are exactly the type of feedback we desire as well, and reinforce the strategy of working with the SWA. Target dates for this symposium are early May 2011.

C. Progress on project objectives for this reporting period:

Objective 1: Identify and map "N hotspots" throughout the Great Bay watershed

Key note: The term 'hot spot' is used to identify an extensive stream site that has shown consistently high nitrogen levels [e.g., nitrate (NO_3^-), ammonium (NH_4^+) and total dissolved nitrogen (TDN)].

Tasks to meet objective: 1) Site selection for extensive study, 2) field sampling of extensive stream sites, 3) laboratory processing of water samples and 4) compile data and develop a map of N "hot spots."

Progress on tasks

During this initial phase, we have selected approximately 250 extensive sites within the watershed of the Great Bay estuary system. These sites were selected as a subset of the Piscataqua watershed catchments (~3500) identified by the NH Geological Survey (NHGS) using 10 meter digital elevation model (DEM) data. Only catchments where the receiving stream was accessible from a road crossing were considered to facilitate field efforts to sample all 250 catchments within a few days. Catchments selected for extensive sampling (Fig. 1) were chosen to represent various land uses with emphasis placed on catchments that had high human population densities and/or impervious surfaces. Efforts were also made to include sites on the main stem of GB tributaries as well as in various areas of the watershed.

The ~ 250 extensive stream sites were sampled in October 2010 and samples have been analyzed for dissolved nitrogen species ((NO_3^-, NH_4^+ and dissolved organic nitrogen (DON)). Preliminary results show that sites have a range of nitrate and TDN concentrations and some are potential N "hotspots" (Fig. 2 and 3). We will resample the extensive hot spot sites two additional times to better characterize the average N concentration at these sites and to develop a Great Bay landscape model that predicts stream water N concentrations based on catchment landscape characteristics and is calibrated to the entire GB watershed. To identify which of the extensive sites are "hot spots" we will first compare the measured N concentrations to N criteria established for GB (0.30 mg/L to protect eelgrass and 0.45 to protect DO levels) and sites that exceed these benchmark criteria may be considered "hot spots." We will also compare measured concentrations to the N concentration predicted by the human population density model developed for the Lamprey and Oyster watershed (Daley et al. 2010) and the new GB landscape model that we will develop. Extensive sites that exhibit noticeably higher N concentrations than the Lamprey and Oyster or GB landscape models predict based on the catchment characteristics will be considered N hot spots. Finally, the GB landscape model will also be used to predict which of the ~3500 Piscataqua catchments have stream water N concentrations that exceed the benchmark N

criteria for GB. If results from the GB nitrogen loading model (NLM) that Phil Trowbridge is developing can be translated to predicted N concentrations at our extensive sites and the ~3500 Piscataqua catchments (in addition to N loading at HUC 12 watersheds which is currently planned), then we will compare the predicted NLM concentrations to measured N concentrations at our extensive sites and to modeled N concentrations for the ~3500 catchments by the GB landscape model.

Objective 2: Identify NPS nitrogen– Intensive study

Tasks to meet objective: 1) Select non-point source (NPS) N intensive study sites, 2) Develop a NPS N multi-tracer method, 3) Establish groundwater well sites, and 4) Sample nutrient and water chemistry at sites.

Progress on tasks
Initial assessment of extensive site data has begun, in order to select ~10 sites for intensive study. We have begun laboratory testing and development of innovative multi-tracer methods to identify the NPS that likely produces individual N hotspots.

Method Development
As part of the chemical tracer approach, we have developed a method to identify concentrations of optical brightener compounds (OBs) in water samples using HPLC and fluorescence spectroscopy. This compound is prevalent as a whitening agent to brighten laundry products and the waste water can travel from homes, businesses and restaurants to streams as storm water runoff. Another compound common associated with non-point source N such as septic waste water is caffeine. Development and testing of a method to trace caffeine compounds has also progressed. Evidence of both caffeine and OB signals can be used to confirm certain NPS inputs.

Through collaboration with a university laboratory (Brown University, Providence, Rhode Island, under the direction of Dr. Hastings), progress has been made on utilizing a bacterial denitrification technique coupled with a dual isotopic method ($\delta^{15}N$ and $\delta^{18}O$) to measure nitrate in stream, ground and rainwater samples at intensive sites. The natural abundance of heavy stable isotopes (i.e., $^{15}N/^{14}N$ and $^{18}O/^{17}O$) integrates ambient nitrogenous compounds in aquatic environments over time within a known range of values. Thus, signatures of water samples can be analyzed to help delineate non-point sources.

Progress has also been made on a method to identify N sources that can be reflected in stream organic matter. Stable isotopic measurements of $\delta^{15}N_{SED}$ (stream sediment) and $\delta^{15}N_{Plant}$ matter have been analyzed at the UNH, Stable Isotope Laboratory under the direction of Dr. Erik Hobbie. Because $\delta^{15}N$ is enriched in manure and sewage, a correlation between elevated nitrate and high $\delta^{15}N$ values can represent particular land use practices.

Objective 3: Identify N delivery pathways at intensive study sites

Tasks to meet objective: At designated intensive sites, characterize the hydrological flow path and nutrient chemistry using the multi-tracer approach (e.g., stable isotope, chemical, and microbial) using data generated from Objectives 1 and 2.

Plan: Use the next six months to; 1) Establish flow path of presumed high N, 2) Test and utilize multi tracer NPS N approach

Objective 4: Examine extent of riparian denitrification with land-uses

***Tasks to meet objective*:** Sample groundwater wells and streams for N removal

Plan: These tasks will occur in year 2.

Objective 5: Examine in-stream nitrate attenuation

***Tasks to meet objective*:** Determine N uptake in river reaches with mass balance and measure $^{15}NO_3$ uptake in the field in low-order streams.

Progress: The task to determine N uptake in river reaches with mass balance has been initiated, but the majority of this GIS analysis will occur over the next 6 months. Measuring $^{15}NO_3$ uptake in the field in low-order streams will occur in year 2.

Objective 6: Integration of science with end users

Progress: The various integration activities as described throughout this report continue to benefit the project direction and goals.

- **Data collected for this reporting period.**

During the extensive watershed wide study, ~250 stream surface water samples were collected from sites selected throughout the Great Bay watershed. Subsequent nutrient analyses were completed among the major N fractions (NO_3^-, NH_4^+, and TDN). Additional water chemistry analyses included measurement of major cations (Na^+, Ca^{+2}, Mg^{+2}, K^+) and anions (Cl^-, SO_4^-). Samples of stream sediment were collected from the surficial (2 cm) benthic layer at selected sites using the stable isotope tracer method as described earlier.

In the laboratory, a series of methods tests has been used to develop the multi-tracer techniques. Relevant spatial (GIS) data for the GB watershed has been compiled. This information is crucial to spatial model completion and mapping products.

- **Unanticipated challenges, opportunities, and/or lessons learned.**

It has been a challenge to translate the complex science issues into a language that the stakeholders can understand and we continually strive to improve the science translation. In

response to these challenges, we have initiated several actions to better communicate the complexity of both the nitrogen pollution issue and specific approach used to accomplish study goals. We have provided information on our newly developed website (http://www.wrrc.unh.edu/greatbayNhotspots/index.html) and anticipate that this type of outreach will serve to inform the community in between workshops.

- **Plans for meeting project objectives for the next six months.**

During the next six months, we will complete Objective 1 and progress toward completing Objective 2 as described above. We will also make progress on Objective 3. Once completed, we will proceed toward completion of Objective 4 (Examine the extent of riparian denitrification with land use) and 5 (Examine in-stream nitrate attenuation). Ongoing communication with our end-user community will be maintained as progress on products generated include the GB landscape model and results from the multi-tracer approach, both of which will allow managers to better estimate what non-point sources of N exist in their town or respective catchment.

Project Website Development
The purpose of the Great Bay Nitrogen project website is to *disseminate project information* and serve as a virtual meeting place for interested parties to become more informed regarding the project science and collaborative activities. Its purpose is also to provide a current stream of information to complement the role of workshops and seminars. Continuous project updates and ongoing exchange between the scientists, stakeholders and community will be maintained.

A next step taken by our collaborative science team in assessing the outreach and collaborative efforts will be to continue to initiate and host workshops with the community For example; a stakeholder review and focus group will be held at the Great Bay's Hugh Gregg Coastal Conservation Center in the next quarter. This review will entail a group of "end users" working through fictitious scenarios on various watershed and coastal issues related to NPS N pollution and how they are impacted in their community. The goal is to work through conflict resolution processes that will be useful during the course of this project. Users will be asked to note any challenges they have in understanding project objectives and specific outcomes and products that they would want developed. All participants will de-brief their opinions through a focus group format and written survey where a relevant questionnaire will be reviewed individually. Time will be allocated to share thoughts about the important parameters to be included for future workshops and shared with end users. A report summarizing the results will be generated and shared with others interested.

D. Benefits to NERRS and NOAA: List of project-related products, accomplishments, or discoveries that may be of interest to scientists or managers working on similar issues that may be of interest to our peers in the NERRS, or to NOAA.

- Presented project summary to the UNH Continuing Education Department, which intends to give our team the opportunity to inform working professionals of the nitrogen issue in the Great Bay.
- The project team presented an overview of the project to shareholders and the community (i.e. recent workshop and symposium) and used these venues as an information forum for generating input on the research questions, as well as community stakeholders' concerns related to impacts of excess nitrogen in the Great Bay.
- Press release resulting in articles in The New Hampshire and local newspapers outlining the project, the need, and the implications to the stakeholder community.
- Article in the Lee Newsletter demonstrates grass-roots interest in the project and desire to become engaged in the research process.
- Website where preliminary findings will be shared, including maps generated from preliminary data.

E. Activities, products, accomplishments, or obstacles not addressed in other sections of this report that may be important for the Science Collaborative to know.

Nitrogen has become a sensitive issue in New Hampshire with the EPA listing of Great Bay as impaired. The Southeast Watershed Alliance has been reticent to tackle the issue since there are conflicting positions maintained by the members of the Alliance. The wastewater treatment representatives in the alliance attribute impairment towards lack of knowledge regarding the role of NPS N from sub basins in nitrogen affecting the bay. The towns without centralized wastewater treatment facilities point to the wastewater treatment facilities as the major source. Stakeholder groups have expressed concern as to whether the scientific results may pin-point N hotspots within their jurisdiction (e.g. reducing N related to inadequate sewage treatment facilities). Through our continued collaborative process, we will address such issues with constituent groups that may not agree on their potential role in administering actions that reduce NPS nitrogen to tributaries and the Great Bay Estuarine Reserve.

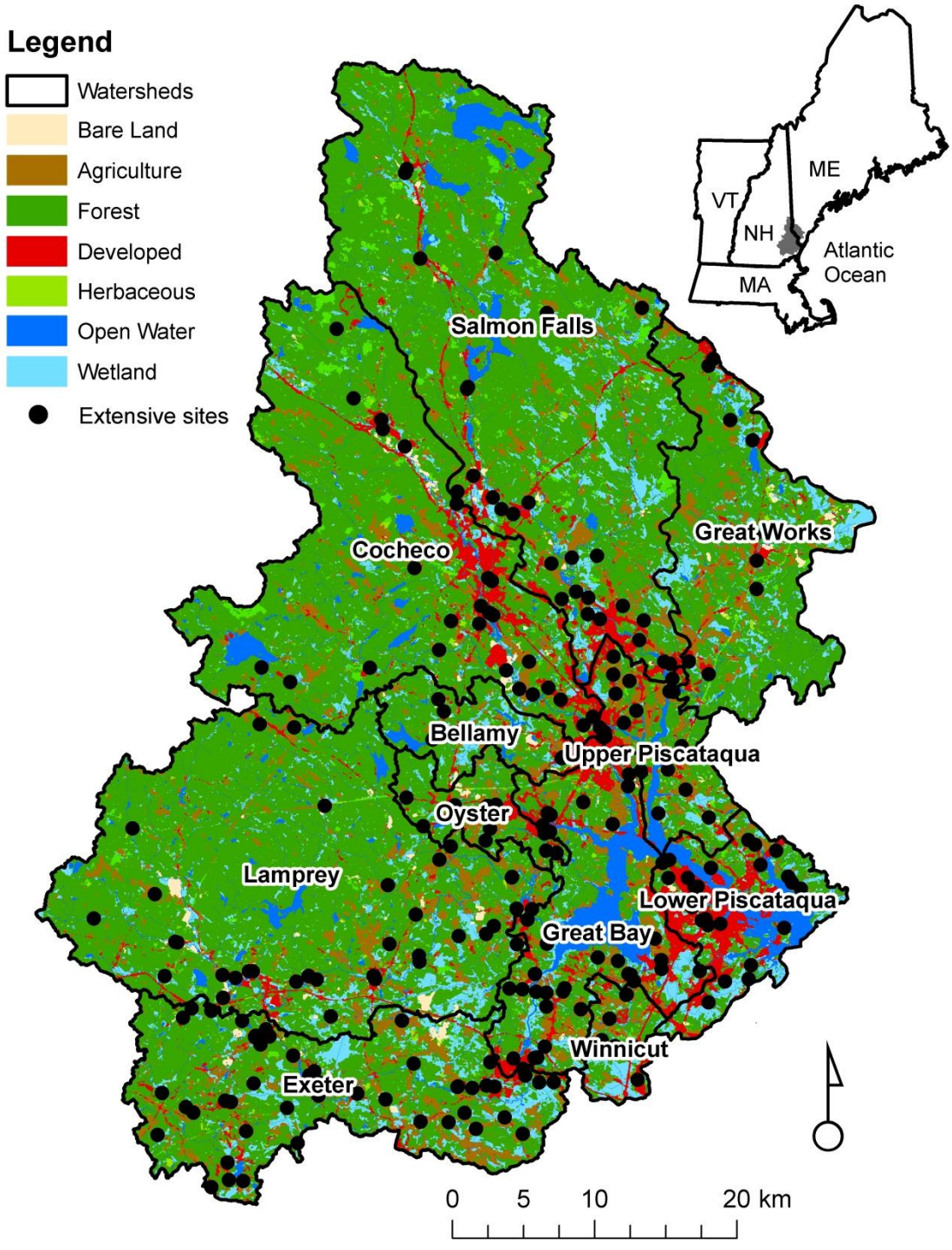

Figure 1: Land use and extensive sampling sites in the Great Bay watershed

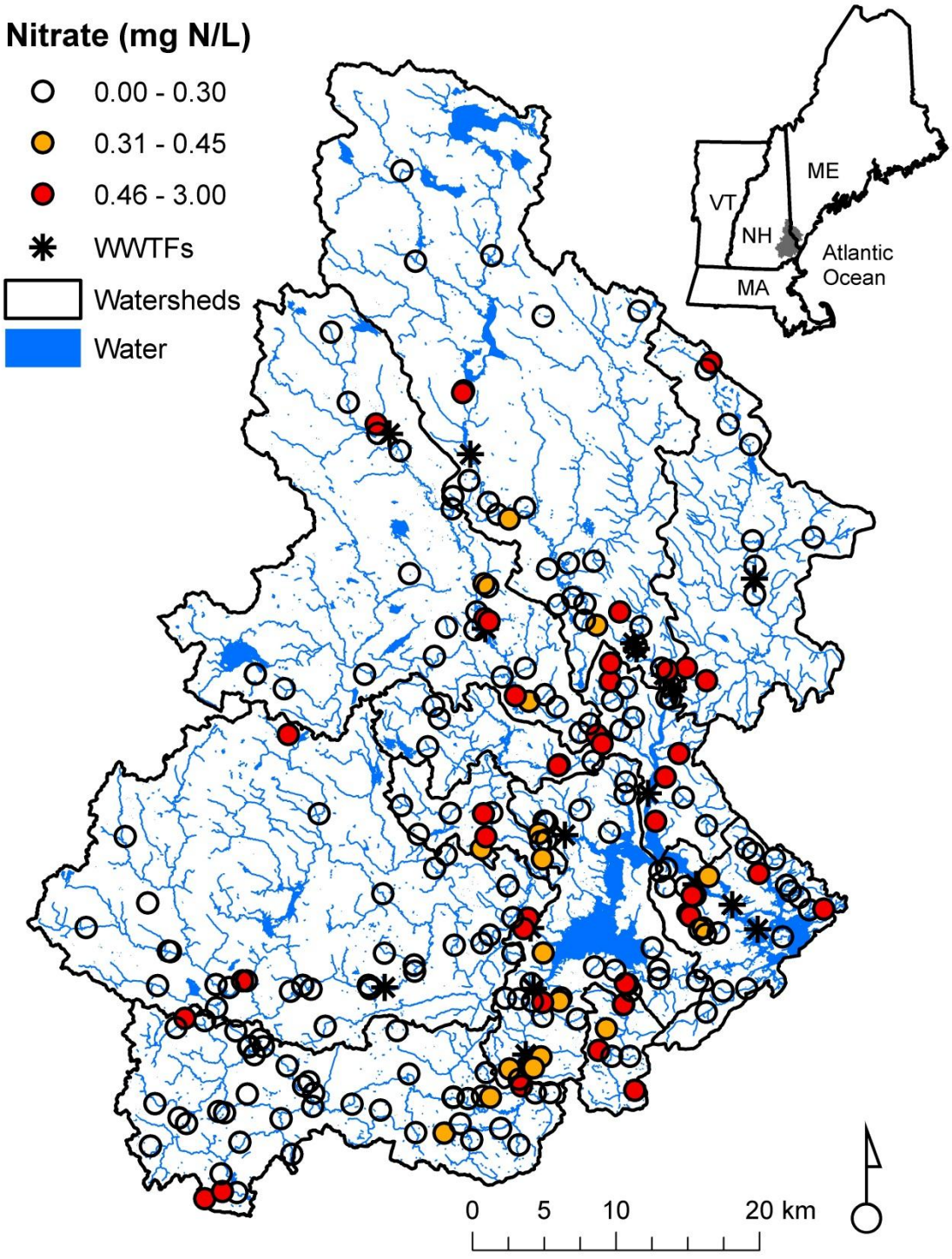

Figure 2: Preliminary nitrate concentration data at extensive stream sites.

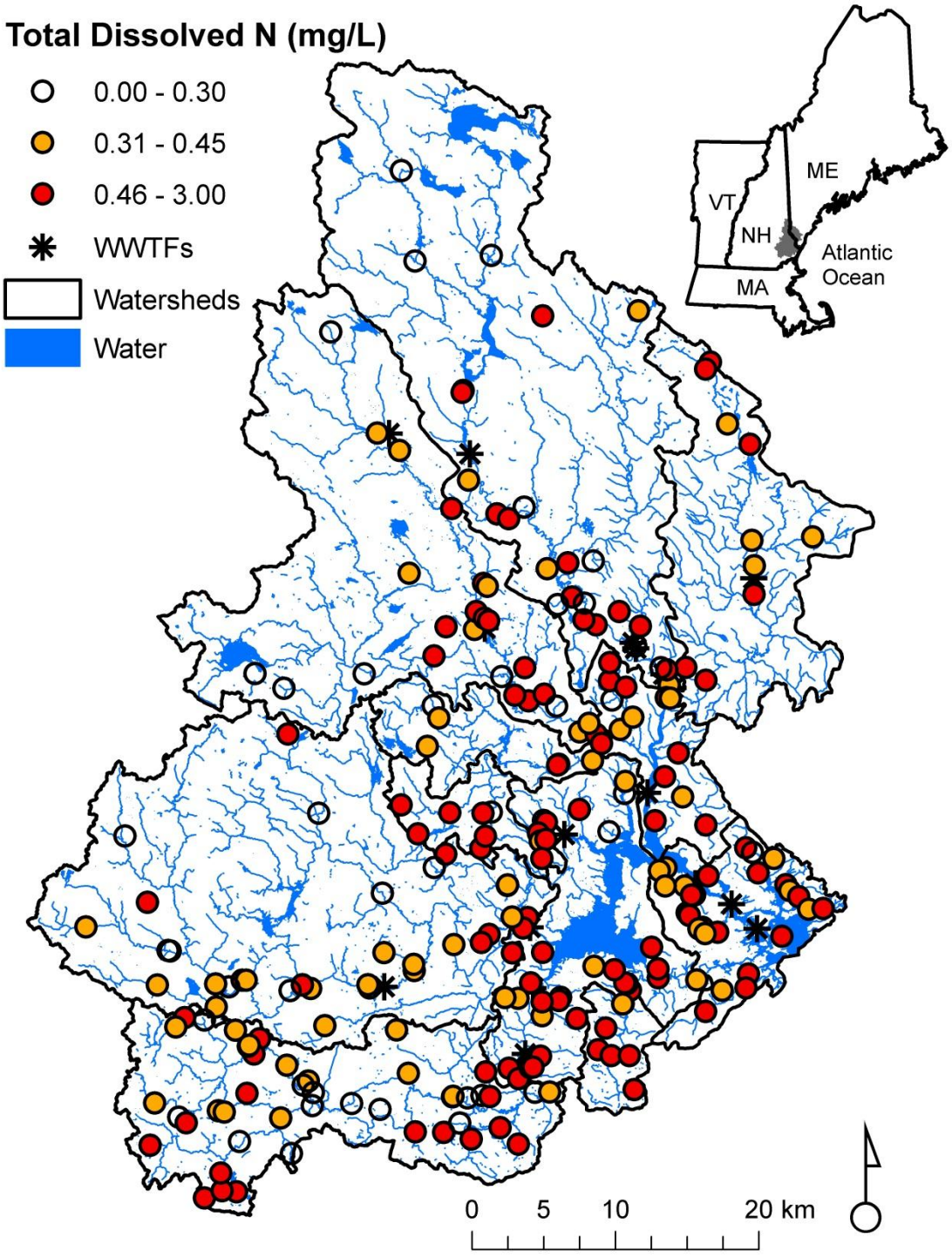

Figure 3: Preliminary total dissolved nitrogen (TDN) concentration data at extensive stream sites.